Abstract

There are various energy dissipation mechanisms that affect the dynamic response of microstructures used in MEMS devices. A cumulative effect of such losses is captured by an important characteristic of the structure called Quality factor or Q-factor. Estimating Q-factor at the design stage is crucial in all applications that use dynamics as their principle mode of operation. A high Q-factor indicates sharp resonance that, in turn, can indicate a broad flat response region of the structure. In addition, a high Q-factor typically indicates a high sensitivity. Microstructures used in MEMS are generally required to have much higher Q-factors than their macro counterparts. However some damping mechanisms present in microstructures can reduce the Q-factor of the structure significantly.

In the present work, we investigate the dependence of Q-factor on the squeeze film damping-an energy dissipation mechanism that dominates by a couple of orders of magnitude over other losses when a fluid (e.g., air) is squeezed through gaps due to vibrations of a microstructure. In particular, we show the effect of nonlinear terms in the analysis of squeeze film damping on the Q-factor of a structure. We also show the effect of rarefaction, surface roughness along with their coupled effect and with different boundary conditions such as open border effect, blocked boundary effect on the squeeze film damping. Finally, we develop similitude laws for calculating squeeze film damping force in up-scaled structures. We illustrate the effects by studying various type of microstructures including parallel plates, beams, plate and beam assemblies such as MEMS microphone, vibratory gyroscope etc.

We view the contributions of this work as a significant in investigating and integrating all important effects altogether on the squeeze film damping, which is a significant factor in the design and analysis of MEMS devices.